

THE EDDY TREE BREEDING STATION

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With the growing interest in reforestation in nearly all parts of the United States, it is natural that some thought should be given to the possibilities in developing improved types of forest trees. The practice of using new and better strains of agricultural crops is now so well established that no one would think of planting the inferior wild forms that were the progenitors of the present highly developed types. Yet in the present-day reforestation activities, all of the seed that is used is of the wild unimproved forms that only partially fulfill the requirements.

Mr. James G. Eddy, a lumberman of Everett, Washington, was one of the first to recognize this need for breeding work with forest trees, and as a result he established the Eddy Tree Breeding Station in the spring of 1925. He felt that one of the principal drawbacks to the planting of forest trees is the comparatively slow rate at which



Fig. 1. General view of nursery of Eddy Tree Breeding Station, showing sprinkling lines over the open beds of two year old seedlings in the foreground, and the enclosed beds of one year old seedlings in the background. The three beds in the immediate foreground contain, from left to right, *Sequoia sempervirens*, *Pinus radiata*, and *Pinus ponderosa*. The tallest of the two year old *P. radiata* seedlings are just 3 feet high.

they normally develop. Hence one of the main objects of the work of the Station is the development of more rapid growing strains of trees that will reach the merchantable size in a shorter time and that will have wood of good quality.

The Ecological Environment of the Experimental Station

After a search over a large part of the Pacific Coast for a suitable location, the site finally selected is a tract of 65 acres of land located about three miles east of Placerville, California. Here was found a wonderful combination of favorable conditions. The Station is situated near the lower edge of the main Western Yellow Pine timber belt, in the central Sierras, at an elevation of about 2,700 feet. All timber species typical of the lower Sierra (including *Pinus ponderosa*, *Pinus lambertiana*, *Pseudotsuga taxifolia*, *Abies concolor*, and *Libocedrus decurrens*) are to be found on the Station grounds or nearby. It is in the center of a belt of the most rapid growing *Pinus ponderosa* to be found in California, or elsewhere, as far as is at present known. The Station is so located that the climate is comparatively mild, making it possible to grow many exotic species that will not stand severe climates. The average growing season at Placerville is unusually long for the timber belt, being 205 days according to a 25 year average of U. S. Weather Bureau data. This



Fig. 2. Ovulate flowers of *Pinus ponderosa jeffreyi*. The photograph was taken several days after the flowers had been pollinated, and the scales have mostly closed together. The needles are just emerging from their sheaths.

gives a period of nearly seven months without killing frost, which is the same as the growing season in central Alabama. Of the other factors that were instrumental in reaching a decision as to the best location for the Station, the most important were soil, topography, and water supply. The Station soil is a deep loose sandy loam of a remarkably uniform character. An even and unbroken topography also contributes toward making conditions very much alike over the whole area.

The character "vigor" is a most difficult one to study from the point of view of heredity, for it is, to a greater extent than almost



Fig. 3. An exceptionally fine cluster of staminate catkins of *Pinus ponderosa jeffreyi*. Observations made in El Dorado County have shown that the color and shape of the catkins is one of the most reliable of field identification marks for distinguishing this variety from the species, when both are growing together. The catkins of *P. ponderosa* are bright red and quite long, while those of the variety *jeffreyi* are yellowish bronze and much shorter.

any other character, affected by varying environmental conditions. It is, therefore, of first importance, in nursery and arboretum experiments, to take every reasonable precaution to keep conditions over the whole area as uniform as possible. Figure 1 shows the experimental nursery area.

The field work of pollination and cone collection is largely in the hands of the Station Forester, Mr. John S. Barnes, while the

nursery and arboretum are under the supervision of the Propagator, Mr. H. M. Lumsden.

Phases of Work of Special Interest to Botanists

The writer feels that there are a number of phases of the experiments that should be of interest to botanists. In the first place, it should be pointed out that the work is being concentrated largely upon the different species of the genus *Pinus*, and a very thorough study of this genus will be made. An arboretum is being established which it is hoped will, in time, include a number of specimens of



Fig. 4. The long slender staminate catkins of *Pinus ponderosa*. Compare with Fig. 3.

all known species of pines. The genus is a large and interesting one, and some difficulty is being experienced in obtaining seed of certain little-known species, particularly the rarer ones native to Mexico, the West Indies, India, and the East Indies. However, the writer has been corresponding with over 100 different organizations in many parts of the world, and already seed has been secured of the 82 different species and varieties marked with an asterisk in the following list, containing 118 species and fairly important varieties. The arrangement is based upon G. R. Shaw's relationship classification of the genus (1), but modified to give emphasis to the economically important species, by classing together several groups of minor ones. Group *Austroales* is given first as it contains more valuable species than any other.

SECTION DIPLOXYLON

SUBSECTION PINASTER

Group Australes

- Pinus apachea*—Apache Pine.
 * " *caribaea*—Slash Pine.
 " *cubensis*.
 * " *echinata*—Shortleaf Pine.
 " *glabra*—Spruce Pine.
 " *lawsoni*—Lawson Pine.
 * " *montezumae*—R o u g h
 branched Mexican Pine.
 * " *montezumae hartwegi*.
 " " *lindleyi*.
 " " *rudis*.
 " *occidentalis*.
 * " *palustris*—Longleaf Pine.
 * " *ponderosa* — Western Yel-
 low Pine.
 " *ponderosa arizonica* — Ari-
 zona Pine.
 " *ponderosa benthamiana* —
 Willamette Foothills Pine.
 " *ponderosa deflexa*.
 * " " *jeffreyi*—Jeffrey
 Pine.
 " *ponderosa macrophylla*—
 Large-leaved W. Yellow
 Pine.
 " *ponderosa malleti*
 " " *mayriana*—Mayr
 Pine.
 " *ponderosa pendula*—Weep-
 ing W. Yellow Pine.
 * " *ponderosa scopulorum*—
 Rocky Mt. Western Yellow
 Pine.
 " *pseudo-strobus*—False Wey-
 mouth Pine.
 " *pseudo-strobus tenuifolia*.
 * " *sondereggeri*—Sonderegger
 Pine.
 * " *taeda*—Loblolly Pine.
 * " *teocote* — Twisted-leaved
 Pine.

Group Insignes

- * *Pinus attenuata*—Knobcone Pine.
 * " *banksiana*—Jack Pine.
 " *clausa*—Sand Pine.

- * *Pinus contorta*—Shore Pine.
 " *greggi*—Gregg Pine.
 * " *halepensis*—Aleppo Pine.
 * " " *brutia*.
 * " *muricata*—Bishop Pine.
 * " *murrayana* — Lodgepole
 Pine.
 * " *oocarpa*.
 * " *patula* — Spreading-leaved
 Pine.
 * " *pinaster*—Cluster Pine.
 * " " *des landes*.
 " " *gigantea*.
 * " " *hamiltoni*.
 " *pithyusa*.
 * " " *stankewiczii*.
 " *pringlei*—Pringle Pine.
 * " *pungens*—Table Mt. Pine.
 * " *radiata*—Monterey Pine.
 " " *aurea* — Golden-
 leaved Monterey Pine.
 * " *radiata binata*—Two-leaved
 Monterey Pine.
 * " *rigida*—Pitch Pine.
 * " *serotina*—Pond Pine.
 * " *virginiana*—Scrub Pine.
 Group Macrocarpae
 * *Pinus coulteri*—Coulter Pine.
 * " *sabiniana*—Digger Pine.
 * " *torreyana*—Torrey Pine.
 Group Lariciones
Pinus brevispica.
 * " *densiflora* — Japanese Red
 Pine.
 * " *densiflora globosa* — Jap-
 anese Globe Pine.
 * " *densiflora umbraculifera*—
 Japanese Umbrella Pine.
 " *funnebris*.
 * " *insularis*—Khasia Pine.
 * " *leucodermis* — Graybark
 Pine.
 * " *luchuensis*—Luchu Pine.
 * " *massoniana*—Masson Pine.
 * " *merkusi*—Tenasserim Pine.
 * " *montana*—Swiss Mt. Pine.
 * " " *mughus* — Mugho
 Pine.
 " *montana pumilio*.

- **Pinus montana uncinata*.
 * " *nigra*—Austrian Pine.
 * " " *calabrica* — Corsican Pine.
 * " " *cebennensis*.
 * " " *pallasiana*.
 " " *taurica*.
 * " *resinosa*—Red Pine.
 * " *sinensis*—Chinese Pine.
 " " *yunnanensis*—Yunnan Pine.
 * " *sinensis densata*.
 * " *sylvestris*—Scotch Pine.
 * " " *argentea*.
 * " " *lapponica*.
 * " " *rigensis* — Riga Scotch Pine.
 * " *sylvestris septentrionalis*.
 " *taiwanensis*.
 * " *thunbergi*—Japanese Black Pine.
 " *tropicalis*.

SUBSECTION PARAPINASTER

- **Pinus canariensis*—Canary Pine.
 * " *leiophylla*—Mexican Yellow Pine.
 " *leiophylla chihuahuana*.
 * " *longifolia*—Long-leaved Indian Pine.
 " *lumholtzi* — Pino Barba Caida.
 * " *pineae*—Italian Stone Pine.
 * " " *fragilis*.

SECTION HAPLOXYLON

Group Strobi

- **Pinus ayacahuite*—Mexican White Pine.
 * " *excelsa*—Himalayan Pine.
 * " *lambertiana*—Sugar Pine.
 * " *monticola*—Western White Pine.
 * " *parviflora*—Japanese White Pine.
 * " *parviflora pentaphylla*.
 * " *peuce*—Macedonian Pine.
 * " *strobus*—White Pine.
 " *uyematsui*.

Soft Pines Other Than Strobi

- **Pinus albicaulis*—Whitebark Pine.
 * " *aristata*—Bristlecone Pine.
 * " *armandi*—Armand Pine.
 " *balfouriana*—Foxtail Pine.
 * " *bungeana*—Lace-bark Pine.
 * " *cembra*—Swiss Stone Pine.
 * " " *sibirica*.
 " *cembroides*—Mexican Stone Pine.
 * " *edulis*—Nut Pine.
 * " *flexilis*—Limber Pine.
 * " *gerardiana*—Gerard Pine.
 * " *koraiensis*—Korean Pine.
 * " *monophylla* — Singleleaf Pine.
 " *nelsoni*—Nelson Pine.
 " *parryana*—Parry Pine.
 * " *pumila*—Dwarf Siberian Pine.

Cross Pollination

The groups following the first in the above list are given in order of their relationship to the group *Australes*, which gives an index to the ease with which crosses of different species can probably be effected. It is interesting to note that there are seven known natural pine hybrids (2, 3) and two species crosses that have been artificially produced, and that all but one are between pairs of species that are in the same relationship group. The list follows:

GROUP AUSTRALES

P. palustris (Longleaf Pine) x *P. taeda* (Loblolly Pine) = *P. sondereggeri*. H. H. Chapman, a natural hybrid occurring in Louisiana.

GROUP INSIGNES x GROUP AUSTRALES

P. rigida (Pitch Pine) x *P. echinata* (Shortleaf Pine). Reported by

G. S. Perry as a natural hybrid growing at Mont Alto, Pennsylvania.

GROUP INSIGNES

- P. murrayana* (Lodgepole Pine) x *P. banksiana* (Jack Pine). Reported by A. C. Holman as a natural hybrid occurring in northern Alberta, Canada.
- P. halepensis* (Aleppo Pine) x *P. pinaster* (Cluster Pine)=*P. halepensi-pinaster* Saporta, a natural hybrid.

GROUP LARICIONES

- P. nigra* (Austrian Pine) x *P. densiflora* (Japanese Red Pine). Hybrid produced by Dr. A. F. Blakeslee in 1914.
- P. sylvestris* (Scotch Pine) x *P. nigra* (Austrian Pine). Hybrid produced by Clotzsch in Germany in 1845.
- P. nigra* (Austrian Pine) x *P. sylvestris* (Scotch Pine)=*P. neilreichiana* Reich., a natural hybrid.
- P. montana* (Swiss Mt. Pine) x *P. sylvestris* (Scotch Pine)=*P. rhaetica* Bruegg., a natural hybrid.
- P. montana* (Swiss Mt. Pine) x *P. nigra* (Austrian Pine)=*P. Wettsteiniana* Fritsch., a natural hybrid.

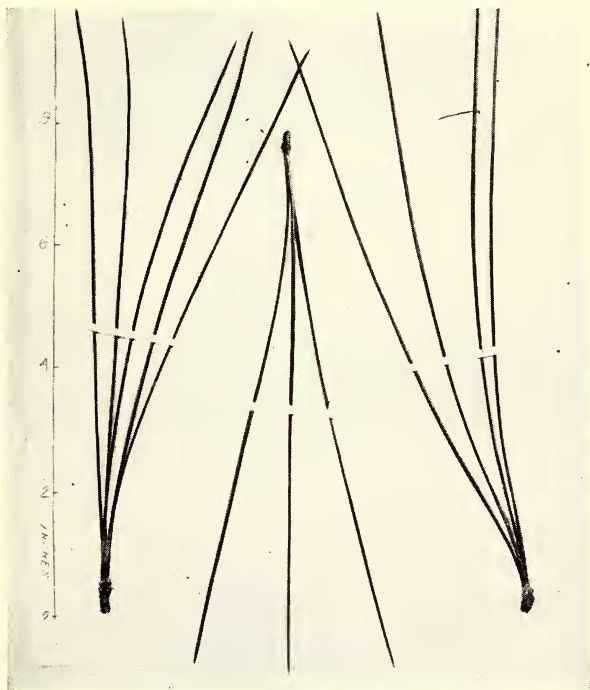


Fig. 5. Illustrating the variability of the needle number in *Pinus ponderosa*, a species which normally has 3-needled clusters. These needle clusters all came from one tree, a tree growing near Camino, California.

The fact that there is only one known cross between *groups* of hard pines, would lead one to believe that such crosses are much more difficult to make than those between species of the same group. However, the small amount of pine pollination which was done in the spring of 1926 has yielded 24 seeds of the cross *Pinus ponderosa* (Western Yellow Pine) x *Pinus montana* (Swiss Mountain Pine) and 29 seeds of the cross *P. ponderosa* x *P. sabiniana* (Digger Pine). Both of these are crosses of species in different groups, but groups which are fairly closely related. The hybrid seeds average nearly as heavy as normal well-filled seeds of *Pinus ponderosa* from this locality, and it is hoped that most of them will prove to be fertile.

The majority of the pollination work in 1927 was done using *Pinus ponderosa* as the female parent. A grand total of 7,648 flowers of this species were hand pollinated and smaller numbers were pollinated of *Pinus radiata*, *Pinus lambertiana*, *Pinus ponderosa jeffreyi*, *Pinus monticola*, *Pinus attenuata*, *Pinus murrayana*, and *Pinus sabiniana*. Pollen of 28 different species of pines were applied to the ovulate flowers of the Western Yellow Pine, in an effort to produce species crosses. In addition to the pollen collected by members of the staff, there was received in the spring of 1927, shipments from 42 different people which included 86 samples of pollen of 33 different species of pines. These shipments came from 23 states and from Canada, Mexico, Guatemala, and the Philippine Islands.

The crossing is being done with two principal objects in view: first, that of securing hybrid vigor, and second that of bringing together in a new hybrid form desirable qualities now occurring in two different species. Inbreeding, which is also being tried, is known to be quite successful in fixing most characters for which selections are commonly made. There may be some doubt, however, as to its effectiveness in the case of the character "vigor", in as much as inbreeding has the reputation of gradually causing a loss in vigor. This, however, does *not* always occur, and the only way to find out the actual effect in a particular case is to try it, as is being done. Giant as well as dwarf strains have been developed by this means.

Tests of Geographical Races

Although it is along this line that many of the European experimenters have worked, very little has been done to isolate geographic forms of species of pines other than those native to Europe. There is then, a wide field of opportunity in studying the relative hereditary characteristics which are transmitted through the seed of a certain species produced in different localities and on different sites. To date, experiments in this direction undertaken by the station have been confined principally to a study of the geographical races of *Pinus ponderosa*, altho the tests are being gradually enlarged to include other species, particularly the four important Southern Pines. In order to "kill two birds with one stone" an endeavor has been made to secure the seed from individual trees in each locality. In this way the tests will serve not only as "Geographical Race Tests"

but also as "Progeny Tests", to be described farther on. Already there are growing in the nursery Western Yellow Pine seedlings from separate trees in British Columbia, Nebraska, Arizona and California, and seed is expected in the fall of 1928 from individual trees of this species growing in Colorado, Oregon, Washington and Montana. As seed crops permit, the localities represented, and the number of trees in each locality will be materially enlarged.

Methods of Finding Superior Parent Trees

It would seem to be comparatively easy to go into a so-called even-aged stand and, by means of systematic measurements and increment borings, determine accurately just which trees of the stand are the largest *for their age*—that is, which ones of a certain age have the greatest cubic volume, as determined by their height, diameter and form. It was found after field trial that this method was hardly feasible for the reason that an increment boring will not give the *exact* age due to the difficulty in counting the rings near the center when the boring is taken at the ground line. When there is uncertainty in this matter it is very difficult to segregate the fastest growing individuals by field measurements.

Another method is being tried in an effort to locate trees in the forest that have the inherent capacity for unusually fast growth. The plan is to base the selection, not upon measurements of the trees themselves, *but upon the relative growth of their progenies in the nursery*. This fundamental principle is widely used by successful breeders of both plants and animals. It should bring to light *hereditary* differences, as these are the only ones that are passed on to the offspring through the seed. The progenies can be compared under the controlled uniform conditions of an experimental nursery; while the parent trees themselves can only be compared under the very diverse growing conditions of Nature in which no two trees have exactly the same surroundings, and in which it is most difficult to tell how much is due to variations in environment and how much to inherent tendencies. Also, this method makes it possible to compare a number of representatives rather than single individuals, and thus strike averages of performance and growing conditions.

The light cone crops of 1926 and 1927 have so far rather restricted this method, but the present plan calls for collecting seed in the fall of 1928 from about 800 individual trees of *Pinus ponderosa* scattered as widely as possible thruout the range of this species. Two plots one-half foot by four feet will be planted in the nursery of each progeny, and at the end of two years' growth, measurements and oven-dry weights of the seedlings will be taken to determine which 200 progenies out of the 800 have made the greatest development. Then seed of these 200, which was collected at the first collection, will again be planted, still allowing only two plots of each. At the end of another two years the number of progenies being saved will be reduced down to the best 60. Then enough seed of each of these will be gathered to plant five plots of each progeny, as the

experiment will by that time have reached the stage where it is practical to *prove* which two or three progenies are the best, by the use of a number of replications. This is hardly feasible in the early stages of the test, where hundreds of progenies are being compared.

Selection Among Nursery Seedlings

The methods last considered have dealt with ways of finding the most rapid growing individual trees in the forest. The present method is intended to bring to light the best individuals in a nursery. Due to the willing cooperation on the part of the majority of the large reforestation nurseries of the country, it has been possible to make selections for vigor among tremendous numbers of trees. In many of the nurseries visited the largest seedlings were picked from among hundreds of thousands of seedlings of a species, and in some cases, the number ran into the millions. It would seem that the relative chances of finding superior individuals is much greater by this method than the other methods that have been discussed, since any one year's work in selecting trees in the forest is likely to have to be limited to a consideration of hundreds, or at most thousands of individuals.

Nursery selection is, for the most part, carried on in seed beds where the seed has come from many trees and there is no record of parentage. Hence it is what the geneticist would call "mass selection." In a naturally *self-fertilized* species, the selection would be directed toward the segregation of the "population" into various pure lines, each having a different rate of growth, and each capable of reproducing itself true to type from seed if pollinated only by individuals of that line. But in naturally *cross-fertilized* plants, such as pines and walnuts, pure lines probably do not exist in the strict sense of the term, as the continual crossing does not allow for their development. In such plants, then, selection can, in the main, only be relied upon to locate individuals whose genetic constitution is heterozygous, but which, if raised to seed bearing age and self-pollinated, might be expected to yield a group of individuals which would exhibit some variation, yet would in general retain the vigor of the mother tree. However, when the selection is made among such large numbers there would also seem to be a fairly good chance of discovering occasionally vigorous mutations, which should come true from seed.

The writer would like to extend to all those who are interested in the work a cordial invitation to visit the experimental Station at Placerville and see the various tests that are under way in the nursery and arboretum. If a visit is not possible, the writer will appreciate hearing from those who are thinking along these lines, and he will welcome criticisms of statements or methods being employed.

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Placerville, Cal., Mar. 27, 1928.